How To Do It

Chaparral & Fire Ecology: Role of Fire in Seed Germination

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In teaching biology, we tend to lecture about solutions, not questions, and our labs teach concepts, not processes. Thus students often leave biology classes still wondering what science is really about. This lab is designed to address these problems and at the same time tie together two subjects usually taught separately—plant structure and function, and ecology. This activity is suitable for students ranging from high school to college at both introductory and advanced levels.

Introduction to the Lab

Plant species have evolved different life histories and germination behaviors as their environments dictate. Dormancy and germination patterns have been correlated with seed structural parameters, such as seed size, thickness of seed coat and type of seed coat (Atwater 1980; Taylorson & Hendricks 1977). In general, germination is blocked by seed morphology and triggered by the environment (Amen 1968).

While some plants appear to require little more to germinate than oxygen, water and the right temperature (e.g. radish), others have more rigid requirements dictated by their environments. This lab focuses on fire annuals and shrubs of California chaparral but could be adapted to any hard-to-germinate plants for which the ecological conditions are known or surmised.

Mature California chaparral consists mainly of small to large shrubs such as sage, chamise, California lilac and sumac. Few herbaceous wildflowers bloom in the spring. By contrast, in the first growing season after a fire, burned areas exhibit a riot of colors from up to 200 recorded species of wildflowers (Keeley & Keeley 1987). The variety and amount of flowers, however, taper off gradually each succeeding year and eventually wildflowers seemingly disappear, not to bloom again for many years until the next fire. These annuals are termed fire annuals because of this behavior (Keeley & Keeley 1987). Other chaparral plants also have seeds that germinate only after a fire has burned the canopy (Keeley et al. 1985).

The seeds of these chaparral plants lie dormant in the soil and do not germinate except under conditions usually present after a fire. Germination is marked by rapid uptake of water, but in these plants the presence of soil moisture is not enough to trigger germination. Two hypotheses have been presented to explain the mechanisms that produce seed germination after fires:

1. Seeds are chemically inhibited by substances produced by mature chaparral shrubs and these chemicals are removed by fire.
2. Seeds receive some stimulus from the fire itself (Keeley et al. 1985).

Both of these hypotheses can be tested in the lab. Since better evidence exists for the second hypothesis, this exercise concentrates on the various effects of the fire itself.

To introduce the concept of germination, first test the variables of light, oxygen and temperature on easy to germinate seeds such as radish and corn. Students should be advised that some seeds have more exacting requirements and that environmental conditions may affect germination. This laboratory exercise, then, is designed to simulate natural conditions of the California chaparral where fires may be relatively frequent, summers are hot and dry, and winters are mild and wet. This activity requires eight to 10 weeks to complete.

Purpose

In this lab students will test several hypotheses to seek to explain why some California chaparral seeds only germinate (or germinate best) after a fire has burned the surrounding chaparral. Variables created by a fire include:

1. The heat from a fire
2. The charred wood left on the ground after a fire
3. Greater light intensity that would reach seeds once the canopy has burned

(Keeley et al. 1985; Keeley 1987; Keeley & Keeley 1987).

More than one of these variables may be important in stimulating germination for a particular plant. Therefore studies will test these variables in combination. They will relate germination conditions in the lab to real life conditions experienced by a plant and develop a general understanding of the role of environment and natural selection on the physiology of seed germination.

Each group will test two or three species. As a control for the germination technique, one group will test an easy-to-germinate species, such as radish, for each of the germination conditions. At the completion of the laboratory, each group will share their results with the class and will write up the lab for all species tested by the class.

Materials

- 150–250 seeds of each species to be tested
- Petri dishes—1 per tested variable for each species

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- Potting soil (Gro-lite recommended) sifted through 1/16" (2 mm) wire mesh
- Oven (accurate up to 200 C)
- Wooden dowels (balsa or birch) or small branches of chamise (*Adenostema fasciculatum*) charred (do not burn to ash) then finely ground to a powder. (Activated charcoal will not work. If a mill is not available to grind the wood, soak the charred wood in water for 24–48 hours and use this extract to water the soil.)

Table 1. Germination of (species tested).*

	Treatment			
	Light		*Dark*	
	Control	*Heat*	*Control*	*Heat*
Control				
Charate				

*Report number germinated out of number sown (--/--)

Procedure

(The procedure that follows is only one of many that can be designed).

Tell students they will be testing the following treatments of seeds: heat (80 C for 30 min. or 120 C for 5 min.), light and charred wood (hereafter called *charate*). By testing charate against a commercial fertilizer or ashed wood charate's effects can be further explored to prove that it is not an inorganic fertilizer.

Seeds are finicky in other ways. Some will require a period of cold treatment and one to two months in a refrigerator will be necessary. Also, all seeds from a species are not alike. One subpopulation will germinate easily without heat or charate, whereas another will not germinate until at least a year after seed fall. The students' job is to try to determine the particular germination requirements for a particular species and relate what happens in the lab to what happens in nature.

Depending on the seed size and quantity available, there will be 10 to 20 seeds per dish for each species.

1. Treat batches of half of the seeds as instructed: heat (80 C for 30 min. or 120 C for 5 min.). Do not heat the other half (control for the effect of heat).
2. Fill eight dishes about half full with moist potting soil (or use dry soil and add a wetting agent to the water in step 5). Label each dish with species, number of seeds and treatment. See table for treatments.
3. Counting the number of seeds sown, sow heat-treated and non heat-treated seeds each into four dishes.
4. Add 0.25 g-0.50 g charate to half the heat-treated and non heat-treated dishes (dishes without control for the effect of charate).
5. Add water to each dish, adding about 5-10 ml (add about 20 ml water if you started with dry soil).
6. Seal dishes with tape and place in plastic bags to prevent drying out. Place dishes in refrigerator (about 4 C) for four to six weeks.
7. Every two weeks, remove and count any seedlings. Add water if necessary to prevent drying out.
8. After cold incubation, remove dishes and incubate at room temperature an additional four weeks. Place one dish with each treatment in dark and count in darkness (control for the effects of light). To count in darkness illuminate seeds with green light only. Incubate the rest in light. Count and remove seedlings every week. Add water as necessary.
9. Show results for each species in a table like the one shown in Table 1.

Discussion & Analysis

1. Write one paragraph identifying which species showed the greatest germination under each condition (heat vs. no heat, light vs. dark, charate vs. no charate and combinations of these). Discuss the conditions that significantly increase or decrease germination rate over another related condition.

(Note: Judge the level of statistical analysis appropriate to your students. This may be a good opportunity to introduce some statistical analysis.)

2. Explain how heat treatment differs from charate treatment in its effects on the seed.

(Heat is a mechanical treatment. Heat may crack the seed coat allowing germination. Charate represents a chemical treatment. Some chemical produced by burned cell walls cues the seed to germinate.)[1]

3. Describe what real life conditions would be necessary for plants whose seeds germinate under the following lab conditions:

a) Seeds incubated in a refrigerator for two months, then at room temperature for two weeks.

(Winter chilling followed by spring warmth).

b) Seeds treated for 24 hours with hydrochloric acid, then sown and watered.

(Passage through an animal digestive tract, then defecation.)

c) Seeds germinate in light but not dark.

(Plant requires full or partial sunlight—seeds germinate if they fall on open ground with no larger plants around.)

d) Seeds germinate in light or will germinate in dark plus charate added.

(Plant requires full or partial sunlight. Once a seed is buried, charate signals that plants above have burned and open ground exists.)

e) Seeds germinate after being heated.

(Plant requires full or partial sunlight. Heating seed signals that surrounding plants have burned.)

Summary—Expected Results, Potential Problems & Additional Activities

The appendix describes expected results for a few species, but many others can be used as available. Figure 1 shows results obtained for radish and buckthorn in one experiment. A good reference for plants is Emery (1964), which describes how to germinate many hard-to-germinate species without regard to ecological conditions. To identify what your plants would look like if you were to grow them to maturity, see Munz's (1961, 1962, 1963, 1964) excellent series on wildflowers. All seeds and books are available by mail (see Appendix).

If you would rather use other or local plants, call your local arboretum and ask for information about fire-evolved ecosystems or hard-to-germinate species in your area of the country. For example, native legumes in the pineywoods of the Southeast are known to be fire-adapted (Cushwa et

[1] Potential answers follow each numbered question and are underlined in the text.

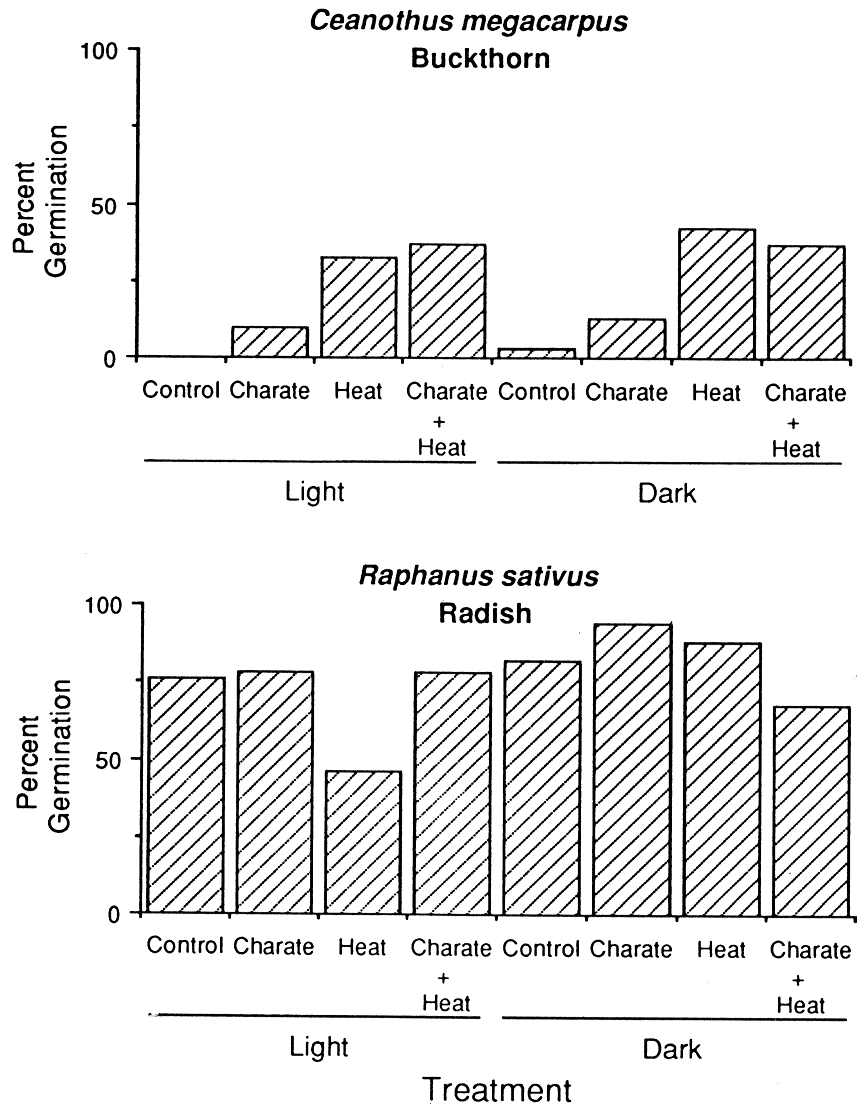

Figure 1. Relationship between germination and seed treatment.

Table 2. Germination requirements for common California plants

Scientific name	*Common name*	*Germination requirements*
Antirrhinum coulterianum	white snapdragon	charate, light
Camissonia californica	camas	charate
Ceanothus integerrimus	deer brush	heat, darkness
Ceanothus megacarpus	buckthorn	heat, charate
Emmenanthe penduliflora	whispering bells	charate
Penstemon spectabilis	penstemon	charate
Phacelia grandiflora	phacelia	charate, no heat
Romneya trichocalyx	matilija poppy	heat and charate; germinate on filter paper, not soil.

al. 1968). The germination requirements of annuals from the Mojave and Sonoran deserts of the Southwest require prolonged high temperatures, such as occur in summer (Capon et al. 1967).

Be aware that some species will not germinate according to expected conditions. Occasionally some species do not germinate at all. This may be because you have a subpopulation of seeds that were too old or too fresh. Even botanists have problems germinating seeds on occasion. For this reason, your students must test a variety of species and combine results for their lab write-up. Remind them that they are experimenting on organisms, and organisms do not always behave as we expect.

This lab can be simplified or extended as you like. To simplify, use only two treatments: heat and charate. Compare the results to controls and graph. Extensions are limited only by materials, time and imagination. Test more plants, try an acid bath or different temperatures for different lengths of time, ashed wood, water extracts of fresh chaparral plants, water extracts or charate, etc. As long as the treatments are based on reality—what might actually be happening in nature—the experiments will be valid. This lab activity would be excellent for a science fair project.

Acknowledgments

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Appendix

Suggested plants and their requirements

The plants on this list have been tested and found to have the following requirements: They are common California plants. Seeds may be ordered from the Theodore Payne Foundation, 10459 Tuxford St., Sun Valley, CA 91352; (818) 768-1802. Request what you need as their published seed lists mainly contain easy-to-germinate seeds; however, they carry many more species than they show on their lists. Other species to use in experiments can be found in the references. Do not use the California wildflower seeds purchased commercially; they are all easy-to-germinate seeds.

References

Amen, R.D. (1968). A model of seed dormancy. *Botanical Review, 34,* 1–31.

Atwater, B.R. (1980). Germination, dormancy and morphology of the seeds of herbaceous ornamental plants. *Seed Science and Technology, 8,* 523–573.

Capon, B. & Van AsDall, W. (1967). Heat pre-treatment as a means of increasing germination of desert annual seeds. *Ecology, 42(2),* 305–306.

Cushwa, C.T., Martin, R.E. & Miller, R.L. (1968). The effects of fire on seed germination. *Journal of Range Management, 21,* pp. 250–254.

Emery, D. (1964). Seed propagation of native California plants. *Leaflets of the Santa Barbara Botanic Garden, 1,* 81–96.

Keeley, J.E. (1987). Role of fire in seed germination of woody taxa in California chaparral. *Ecology, 68(2),* 434–443.

Keeley, J.E. & Keeley, S.C. (1987). Role of fire in the germination of chaparral herbs and suffrutescents. *Madrono, 34(3),* 240–249.

Keeley, J.E., Morton, B.A., Pedrosa, A. & Trotter, P. (1985). Role of allelopathy, heat and charred wood in the germination of chaparral herbs and suffrutescents. *Journal of Ecology, 73,* 445–458.

Munz, P. (1961). *California spring wildflowers.* Berkeley: University of California Press.

Munz, P. (1962). *California desert wildflowers.* Berkeley: University of California Press.

Munz, P. (1963). *California mountain wildflowers.* Berkeley: University of California Press.

Munz, P. (1964). *Shore wildflowers of California, Oregon, and Washington.* Berkeley: University of California Press.

Taylorson, R.B. & Hendricks, S.B. (1977). Dormancy in seeds. *Annual Review of Plant Physiology, 28,* 331–354.